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Supplemental Report 7 - Part I

NASA PROGRAM GEMINI WORKING PAPER NO. 5044

HF COMMUNICATIONS SPACECRAFT-TO-GROUND TESTS PERFORMED DURING GEMINI V MISSION

Issued as: Supplemental Report 7 - Part I

To : Gemini Program Mission Report - Gemini V MSC-G-R-65-4

By : Gemini V Mission Evaluation Team

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
April 12, 1966

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Prepared by

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AUTHORIZED FOR DISTRIBUTION BY

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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ABBREVIATIONS

AGC	Automatic gain control
AOS	Acquisition of signal
AZ	Azimuth
BW	Bandwidth
cps	Cycles per second
CW	Continuous wave
dB	Decibel
G.m.t.	Greenwich mean time
G/S	Ground-to-spacecraft
HF	High frequency
IF	Intermediate frequency
Lat	Latitude
Long	Longitude
LOS	Loss of signal
Mc/sec	Megacycles per second
N	Noise
n.mi.	Nautical mile
PCA	Point of closest approach
rev.	Revolution
RF	Radiofrequency
SC	Spacecraft
S/G	Spacecraft-to-ground
S+N	Signal plus noise

$\frac{S+N}{N}$	Signal plus noise-to-noise ratio
S/S	Signal strength
T/R	Transmitter and receiver
μV	Microvolts

Gemini Network Tracking Stations

The following is a list of the tracking stations from which signal strength and audio tapes were received for HF test no. 1, revolution 51/52:

GTI	Grand Turk Island
BDA	Bermuda
CYI	Grand Canary Island
ASC	Ascension Island
ANT	Antiqua
KNO	Kano, Nigeria
PRE	Pretoria, South Africa
TAN	Tananarive
CRO	Carnarvon, West Australia
CTN	Canton Island
HAW	Kauai, Hawaii
CAL	Pt Arguello, California
GYM	Guaymas, Mexico
TEX	Corpus Christi, Texas
RKV	Rose Knot Ship
CSQ	Coastal Sentry Ship
WHE	Wheeling Ship

1.0 INTRODUCTION

A special spacecraft-to-ground (S/G) and ground-to-spacecraft (G/S) test of the Gemini HF voice communications system was conducted during the Gemini V mission to evaluate system performance under actual flight conditions. Four separate tests were originally planned by the Gemini Program Office, Manned Spacecraft Center. However, because of required changes in the mission flight plan, two of the four tests planned were cancelled. The remaining two tests were conducted during revolutions 51/52 and 63/64, starting and ending each test in the vicinity of the Hawaii Tracking Station.

During the later part of revolution 63, the G/S test was started and continued through revolution 64; Hawaii transmitted voice and tone at 5-minute intervals. The flight crew reported receiving only two transmissions, one near Hawaii and one as the spacecraft approached the coast of Africa. The voice and tone received, together with the time, were to have been entered on the spacecraft recorder, which had failed prior to the start of the test. Consequently, data for evaluation were not recorded. Data were obtained for the entire S/G transmission test conducted during revolutions 51/52.

It is the purpose of this report to present an evaluation of system performance based on the signal strength measurements and voice audio tapes as recorded by the ground network stations during the later test.

The test was conducted utilizing operational personnel to collect the data through the worldwide Manned Space Flight Network during an operational mission. Consequently, it must be recognized that the test data were not gathered by test personnel under the controlled conditions, as would be the case in the customary engineering test.

2.0 GEMINI HF VOICE COMMUNICATIONS SYSTEM

2.1 Ground Station HF Voice Equipment

The ground HF voice equipment at a typical network station consists of a dual transmitting and receiving system. Each system radiates and receives over a separate antenna. An itemized list of the equipment utilized and its operating characteristics are presented in table 2-I. The configuration varies from station to station, particularly regarding the antennas used. In general, five different types of antennas are used, namely:

(1) Vertically polarized whip

(2) Horizontally polarized whip

(3) Dipole antenna with reflector

(4) Three-element Yagi array, horizontally polarized

(5) Terminated rhombic

The gain for the above antennas varies from 1.5 dB for the whip antennas to 6.5 dB for the dipole antenna with reflector.

2.2 Gemini Spacecraft HF Voice Equipment

As shown in the following block diagram, the system consists of a single transmitter-and-receiver unit which, while in orbit, radiates and receives over a whip antenna located in the adapter section or over a similar antenna located in the reentry module, which is used generally during the recovery phase of a mission.

The transmitter and receiver are fixed tuned to a frequency of 15.016 Mc/sec. The transmitter is amplitude modulated and provides an RF power output of 5 watts. Actuation of either the receiver or the transmitter is accomplished through the voice control center. The voice transmitter is also used for transmitting a 1000 cps tone which is used for direction finding.

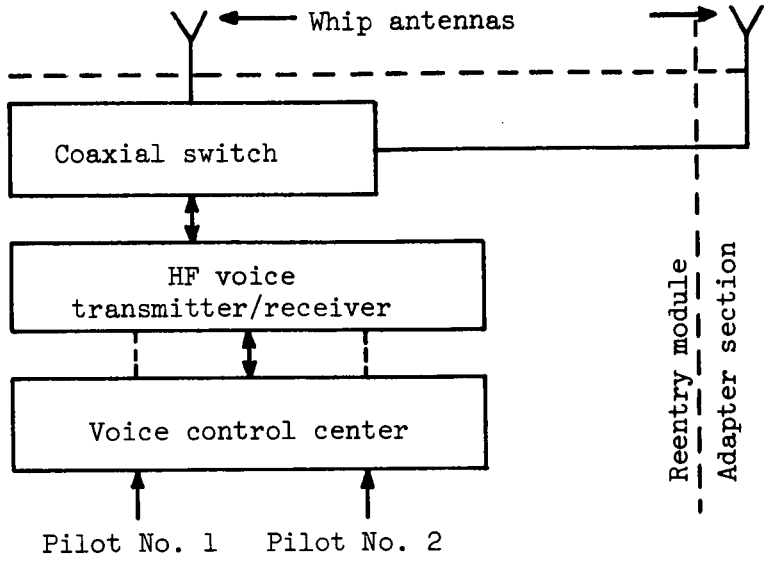
Whip antennas
Coaxial switch
HF voice
transmitter/receiver
Voice control center
Pilot No. 1
Pilot No. 2
Reentry module
Adapter section

TABLE 2-I.- GEMINI V MISSION, TYPICAL NETWORK STATION,

HF COMMUNICATION INSTRUMENTATION

Quantity	Subsystem	Type	Remarks
1	Transmitter (1) Power output (2) Frequency range (3) Frequency stability (4) Modulation	CS-2029	 (1) 250 watts (2) From 14 to 31 Mc/sec (3) 5×10^{-4} percent (4) Amplitude modulated continuous wave
2	Receiver (1) Circuit (2) Frequency range (3) Types of reception (4) Calibration (5) IF selectivity (bandwidth) (6) 1st Variable IF (7) 2nd Variable IF (8) 3rd Fixed IF	R-390A/URR	 (1) Triple conversion superheterodyne (2) 0.5 to 32 Mc/sec (3) Voice modulated continuous wave (4) Crystal controlled (5) 100 cps to 16 kcps (in six steps)[b] (6) 17.5 Mc/sec (7) 3.0 to 2.0 Mc/sec (8) 455 kc/sec
2	Antennas[a] (1) Dipole, horizontally polarized (2) Whip, vertically polarized		 (1) 6.0 dB gain (2) 1.5 dB gain
2	Sanborn recorder	958	8 channels

[a]The antenna systems vary from station to station.

[b]For the Gemini missions, the network operating instructions call for the bandwidth to be set at 8 kc/sec.

3.0 TESTS CONDUCTED

3.1 Test Procedure

The S/G test was conducted from 22:55:00 G.m.t., on 23 August to 00:27:00 G.m.t., on 24 August, or began shortly after Hawaii AOS on revolution 51 and ended in the vicinity of Hawaii on revolution 52. The ground track of the spacecraft during this period is plotted in figure 3-1.

At the start of the test the astronaut annotated the G.m.t. on the voice recorder. At intervals of approximately 5 minutes, the HF voice transmitter was switched off for 2 seconds to permit the ground stations to record the noise level at the input of the ground receivers. Immediately after this 2-second interruption, the astronaut, using the push-to-talk key, would activate the HF transmitter, and repeat the following message twice: "This is Gemini V transmitting on HF, 1, 2, 3, 4, 5, 4, 3, 2, 1." This is followed by giving the G.m.t. in hours and minutes. The transmitter was then operated in the HF/DF (directional-finding) mode which provides 6 watts of continuous wave (CW) modulated by a 1000 cps tone for the remainder of the 5-minute interval. This sequence was repeated at 5-minute intervals for 1 complete orbit. The time of each voice transmission is indicated by a circle (Q) on the spacecraft ground track on figure 3-1.

3.2 Test Results

During the above series of transmissions each ground station recorded the signal strength in microvolts at the input of each ground receiver correlated with the G.m.t. on the Sanborn strip charts, an example of which is shown in figure 3-2. The received HF audio (voice and tone) was recorded on the ground station tape recorders.

The actual trajectory of the spacecraft for revolution 51/52 on the Gemini V mission was obtained from the empheris data (table 3-I). The position of the spacecraft (fig. 3-1) in degrees of latitude and longitude, and the height of the spacecraft in feet above the earth were sampled at 2 1/2-minute intervals.

TABLE 3-I.- GEMINI V MISSION, ACTUAL TRAJECTORY DURING SPECIAL HF COMMUNICATIONS TEST NO. 1, REV. 51/52

Time, G.m.t., hr:min:sec	Geodetic location		Altitude		Comments
	Latitude, degrees (a)	Longitude, degrees (b)	ft	n. mi.	
22:55:00	+9.27	-133.87	728 600	121	
57:30	+3.86	-125.85	755 400	124	
23:00:00	-1.63	-117.95	785 100	130	
02:30	-7.06	-110.04	816 800	135	
05:00	-12.37	-101.95	849 600	140	
07:30	-17.27	-93.55	882 100	145	
10:00	-21.78	-84.70	913 300	150	
12:30	-25.71	-75.32	941 800	155	S/C in darkness
15:00	-28.90	-65.35	966 600	159	from approximately
17:30	-31.21	-54.83	986 600	163	50° W longitude to 85° E longitude
20:00	-32.52	-43.90	1 001 200	165	
23:22:30	-32.74	-32.78	1 009 800	166	
25:00	-31.88	-21.76	1 012 100	167	Apogee
27:30	-29.98	-11.07	1 008 100	166	
30:00	-27.15	-00.90	998 200	165	
32:30	-23.53	+8.69	982 700	161	
33:30	-21.90	+12.36	975 100	160	
40:00	-9.42	+34.37	911 000	150	
42:30	-4.10	+42.28	881 200	145	
45:00	+1.34	+50.10	851 800	141	
47:30	+6.76	+58.00	821 700	135	
50:00	+12.04	+66.07	792 500	130	
52:30	+17.05	+74.52	764 800	126	
55:00	+21.64	+83.47	739 300	122	
57:30	+25.66	+93.03	716 700	117	
00:00:00	+28.92	+103.24	697 100	115	
00:02:30	+31.28	+114.07	681 100	112	
05:00	+32.57	+125.37	669 100	110	
07:30	+32.71	+136.86	661 000	109	
10:00	+31.69	+148.24	657 400	108	
12:30	+29.58	+159.23	658 300	108	
15:00	+26.50	+164.64	664 000	109	
17:30	+22.62	+179.40	674 500	111	
20:00	+18.12	-171.46	689 600	113	
22:30	+13.15	-162.84	709 300	117	
25:00	+7.88	-154.62	733 100	121	
27:00	+3.53	-148.23	754 800	124	

[a] Minus designates degrees south latitude, plus designates degrees north latitude.

[b] Minus designates degrees west longitude, plus designates degrees east longitude.

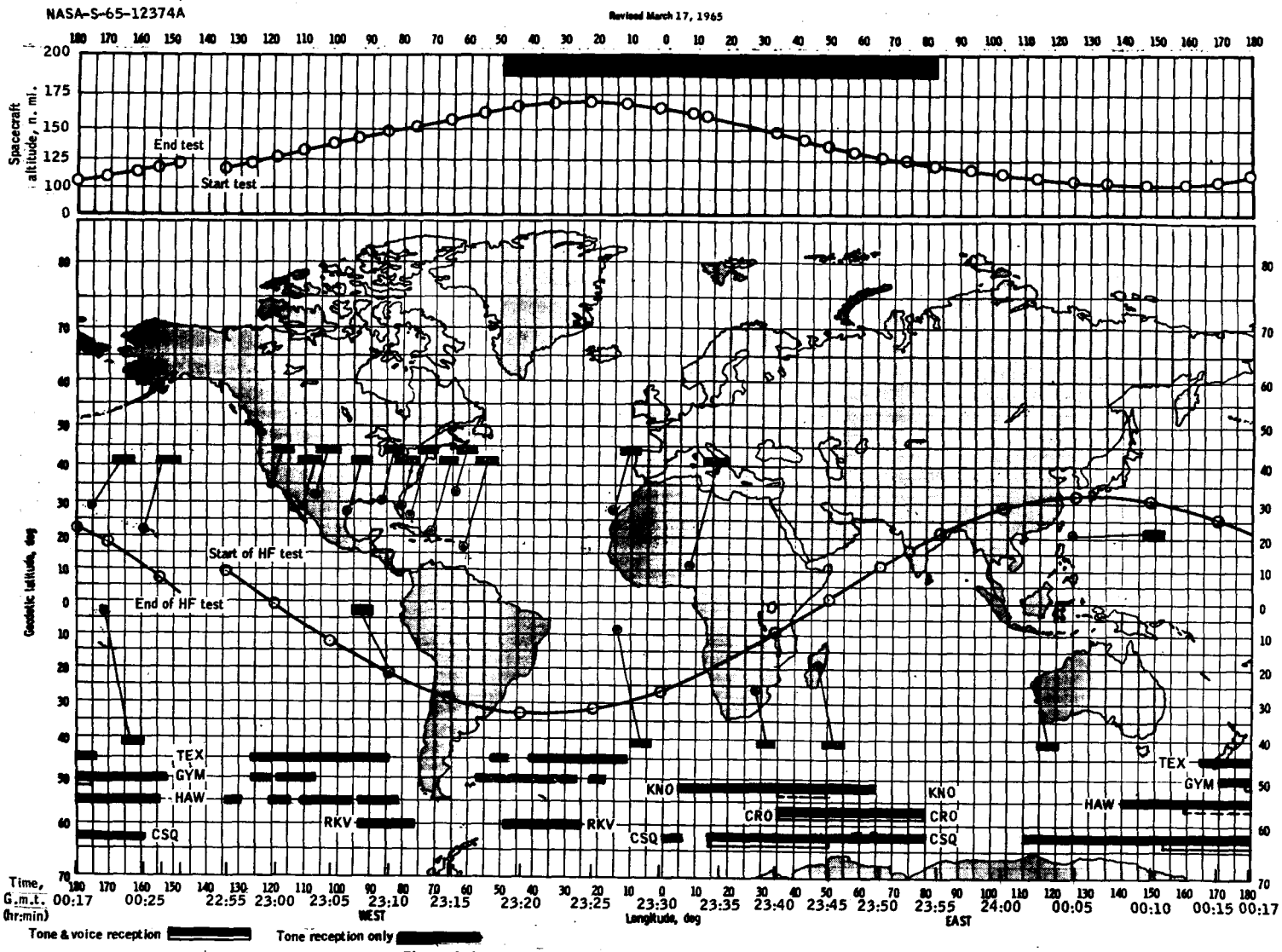

Figure 3-1. - Ground track of Gemini SC during HF test no. 1, rev. 51/52.

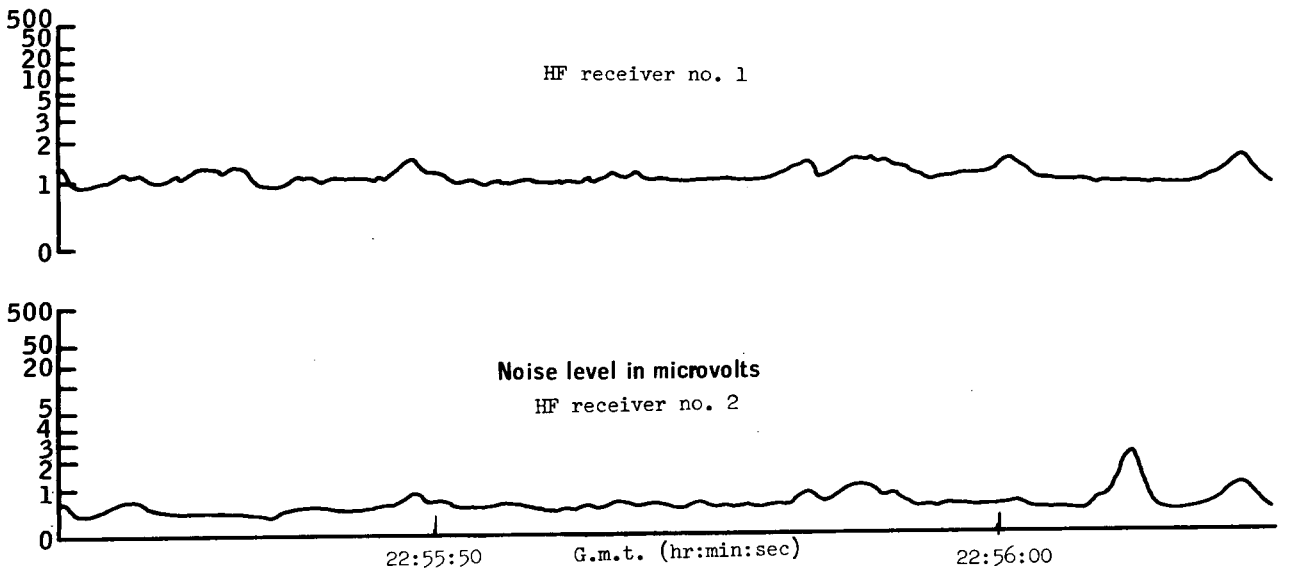

Figure 3-2. - Tracking station CSQ, signal strength chart.

4.0 EVALUATION OF TEST DATA

The magnetic tapes of recorded voice and tone were obtained from 15 tracking stations. These were played back and evaluated. The characteristics of the data recorded by each station are summarized in table 4-I. These results are recapitulated as follows:

(1) Voice tapes were not received for Tracking Stations BDA or PRE.

(2) The tapes received from Tracking Stations ANT, CYI, CTN, TAN, and WHE contained no noise or modulation of any type.

(3) Tracking Stations ASC, GTK, and CAL had excessive noise with intermittent broken signals which could not be identified as Gemini V transmissions.

(4) Tracking Stations KNO, CRO, CSQ, HAW, GYM, TEX, and RKV had tone signals at intervals as shown in figure 3-1. These tones were identified as Gemini V transmissions.

(5) Four of the seven tracking stations listed in (4) received voice at intervals. These were stations KNO, CRO, CSQ, and GYM. As the spacecraft was passing over the station (fig. 3-1), RKV received two unreadable voice transmissions which could not be identified as Gemini V transmissions.

The signal strength recordings from 17 tracking stations were received and evaluated. The noise level and signal plus noise in microvolts were sampled at each 5-minute test interval, throughout the entire orbit, for each station that received an identifiable signal. The general characteristics of the signals received at each station are summarized in table 4-I. Also, the voice and tone reception as a function of time and distance from spacecraft to ground tracking stations is shown in figure 3-1. The results generally agree with the findings obtained from the audio tapes and are further summarized as follows:

(1) The signal strength charts received from Tracking Stations ANT, CYI, CRO, TAN, and WHE reflected zero noise and zero signal plus noise throughout the entire test. The S/S chart for Tracking Station CRO could not be found for revolution 52.

(2) The charts received from Tracking Stations ASC, GTK, BDA, PRE, and CTN contained excessive noise but no signal. Station CAL received intermittent signals that could not be identified as Gemini V transmissions.

(3) Tracking Stations KNO, CSQ, HAW, GYM, TEX, and RKV received intermittent tone signals at various times throughout the test. Station CRO received voice and tone at intervals. The time at which each station received voice and tone is plotted in figure 3-1.

The seven stations which received tone provided approximately 75 percent coverage around the earth. Because the duration of the voice transmissions was approximately 20 seconds out of each 5-minute period for 17 transmissions, the percentage of worldwide voice coverage cannot be accurately determined. However, as previously mentioned, the performance was not satisfactory. Four stations received identifiable voice for nine transmissions. Of these, only three transmissions were of good quality; six were garbled and fading. The overall system performance was far below the required minimum.

Atmospheric noise appeared to be the major limitation to HF communications at the Gemini frequency (15.016 Mc/sec). Atmospheric interference is produced mostly by lightning discharges and, in certain areas, dust storms in the vicinity of the receiving antenna.

Interference was particularly intense at the stations located in the Caribbean (GTK, CYI, and ANT) and at the stations located in Africa (KNO, PRE, and TAN). During this test, KNO received only two garbled and fading voice transmissions and intermittent tone for approximately 12 minutes. During the entire test, the remaining five stations did not receive either voice or tone. However, the noise level at these stations was unusually high. At KNO, for example, the noise level varied from 5 to 100 μV for extended periods (fig. 4-1). The only voice or tone received at this station occurred during periods when the noise dropped to 5 μV. The best tone and voice reception was obtained by the Coastal Sentry ship (CSQ) which was stationed at latitude 21° N and longitude 125° E (table 4-III). The noise level and signal plus noise were sampled at each 5-minute interval corresponding to the time of each test sequence and corresponding to the signal plus noise-to-noise ratio calculated; these results are depicted in table 4-III. This tabulation shows that the noise level averaged about 1 μV for the first 35 minutes of the test and increased to an average of 2.5 μV with an occasional peak of 5 to 6 μV for the last 55 minutes. The table also shows that reception (both voice and tone) was excellent when the signal plus noise-to-noise ratio was 10 or more decibels.

It was significant that six stations received intermittent voice and tone while the spacecraft was orbiting at an altitude of 150 to 167 nautical miles during the period from 75.3° W longitude to 40° E longitude and from 9.4° S latitude to 31.9° S latitude (fig. 3-1).

This would place the spacecraft within the average ionization intensity of the F_2 layer of the ionosphere. Also, this would imply that the signals received were not reflections from the ionosphere (the normal over-the-horizon mode of propagation) but were propagated by ducting through the ionosphere. However, a larger sampling of test data including information regarding ionosphere structure at the time of the tests is needed to confirm this implication.

At the Texas and Guaymas stations one receiver has a vertically polarized whip antenna and the other receiver has a horizontally polarized dipole antenna. The noise level was much higher on the vertically polarized whip antenna; consequently, no readable tone or voice was obtained on this receiver.

As indicated in table 4-II, Tracking Station RKV located at 22° S latitude and 85° W longitude experienced very intense noise and interference throughout the test, and only two garbled and fading voice transmissions were received while the spacecraft was passing overhead at an altitude of 150 nautical miles (fig. 3-1). Apparently, the interaction between the direct ray and the ionosphere reflected ray was responsible for this fading effect (an occurrence common to communications at high frequencies using amplitude modulation).

TABLE 4-I.- SUMMARY OF GEMINI V MISSION, HF VOICE AND TONE RECEPTION, SPECIAL HF VOICE COMMUNICATIONS TEST NO. 1, REV. 51/52

Station	Comments
BDA	Voice tape was not received.
GTK	Contained noise only. No voice or tone throughout. The communications technician announced on the tape each change of antenna orientation.
ANT	No tone or voice, S/S recording indicated $\frac{S+N}{N}$ = 1 through test.
ASC	Unreadable voice and intermittent tone at intervals which could not be identified as GT-5 transmissions.
CYI	No voice or tone, S/S recording indicated $\frac{S+N}{N}$ = 1 throughout test.
KNO	Tone from [a]23:30:00 to 23:40:00. Voice and tone 23:40:00 to 23:50:00; tone only to 23:54:30.
PRE	Voice tape was not received.
TAN	Audio tape contained neither signal nor noise throughout test.
CRO	Voice and tone 23:35:00 to 23:55:00; tone only 23:55:00 to 00:01:45.
CSQ	Voice and tone 23:35:00 to 23:45:00; tone only 23:45:00 to 00:12:50; voice and tone 00:13:00 to 00:25:00.
CTN	No voice or tone throughout test.
HAW	Tone at 23:50 to 23:56,23:07 to 23:10 to 23:27; two garbled, unreadable voice transmissions at 00:13 and 17:20.
CAL	Intermittent broken signals with no modulation that could be identified as Gemini-5 transmissions.
GYM	Tone only at intervals throughout rev. 51/52; voice from 00:15:30 to 00:17:25; tone only to 00:25:00.
TEX	Texas tone only at intervals of 1 to 5 minutes for a total of 16 minutes and 35 seconds.
RKV	Two unreadable voice transmissions were received at 23:05:30 and at 23:17:00; weak tone was received at 23:07 to 23:12, 23:14 to 23:16, and 23:19 to 23:24. These transmissions were received while the vehicle was passing overhead.
WHE	No noise or signal recorded on the tape received from WHE.

[a]G.m.t. (hr:min:sec).

TABLE 4-II.- SUMMARY OF HF VOICE SIGNAL STRENGTH RECEIVED BY EACH TRACKING STATION DURING HF COMMUNICATIONS TEST NO. 1, REV. 51/52

Station	Comments
BDA	No identifiable signal throughout the test (20 μV noise maximum with an average 7.5 μV).
ANT	S/S chart did not contain noise or signal throughout the test.
ASC	S/S recording indicated a S+N of 3 to 70 μV throughout the test, but no readable signal received.
CYI	S/S recording did not indicate either signal or noise throughout the test.
KNO	Tone from [a]23:27:00 to 23:54:30, voice from 23:40 to 23:50, noise level 5 μV, S+N = 25 μV for voice, receiver no. 2 only indicated noise.
PRE	S/S chart contained noise only with no identifiable signal throughout the test.
TAN	S/S chart did not indicate noise or signal throughout the test.
CRO	S/S record for rev. 51 contained neither signal nor noise. S/S for rev. 52 could not be located.
CSQ	Noise level 2 μV from 22:55:00 to 23:30:00, voice and tone received at intervals. Clear voice received for a $\frac{S+N}{N}$ of 10 dB.
CTN	No signal or noise until the last 15 minutes of the test from 00:10 to 00:25. The noise averaged 5 μV with no signal throughout.
HAW	Average noise level was 10 μV, maximum signal plus noise 15 μV. Intermittent tone and two garbled voice transmissions received 00:13:00 to 00:17:20.
CAL	Noise level averaged 10 μV throughout test. Three minutes of tone received near the end of the test.
GYM	Noise level varied between 2 and 5 μV throughout test. Signal and noise increased to 5 μV on tone only near the end of the test.
GYM	Noise level varied between 2 and 5 μV throughout test. Signal and noise increased to 5 μV on tone only near the end of the test.
TEX	Signal plus noise averaged 10 μV with a maximum of 30 μV. Tone was received intermittently for a total of 17 minutes - no voice.
RKV	Noise and interference level was very high during test. Weak signal received while SC was passing directly over the station.
GTK	Average noise level 4.5 μV throughout test. No readable signal was received.
WHE	S/S recording indicated no signal throughout test.

[a]G.m.t. (hr:min:sec).

TABLE 4-III.- GEMINI-V MISSION, SIGNAL STRENGTH RECEIVED DURING HF COMMUNICATIONS TEST NO. 1, REV. 51/52, TRACKING STATION CSQ

Time G.m.t., hr:min:sec	Average noise, μV	[a] $\frac{S+N}{}$ μV	[b] $\frac{S+N}{N}$ dB	Comments
22:55:00	1.0	1.0	0	Antenna AZ = 47°
23:00:00	1.25	1.25	0	
05:30	1.0	1.0	0	No signal or tone from
10:00	1.2	1.2	0	22:55:00 to 23:30:00
15:00	1.0	1.0	0	
17:00	1.25	1.25	0	
20:15	1.5	1.5	0	
25:00	1.2	1.2	0	
30:00	2.0	2.5	1.6	Weak tone
35:00	1.25	2.5	6.0	Intermittent voice and tone
40:00	3.0	8.0	10.0	Very clear voice and tone antenna AZ angle set to 320 degrees
45:00	2.0	5.0	8.0	Intermittent voice and tone
50:00	5.0	10.0	6.0	Tone intermittent
55:00	2.5	4.0	4.4	Neither voice nor tone
00:01:45	4.0	8.0	7.0	Tone only
00:07:00	2.7	4.2	3.0	Tone and voice not being transmitted
00:11:50	5.0	20.0	14.0	Tone received, voice not transmitted, antenna AZ angle = 35 degrees
00:12:10	6.0	20.0	11.0	Tone and voice not being transmitted.
00:13:00	4.0	20.0	14.3	Excellent voice and tone
00:17:30	3.0	5.0	2.0	Tone
00:25:00	3.5	5.0	2.6	Tone

[a] Signal plus noise.

[b] Signal plus noise-to-noise ratio.

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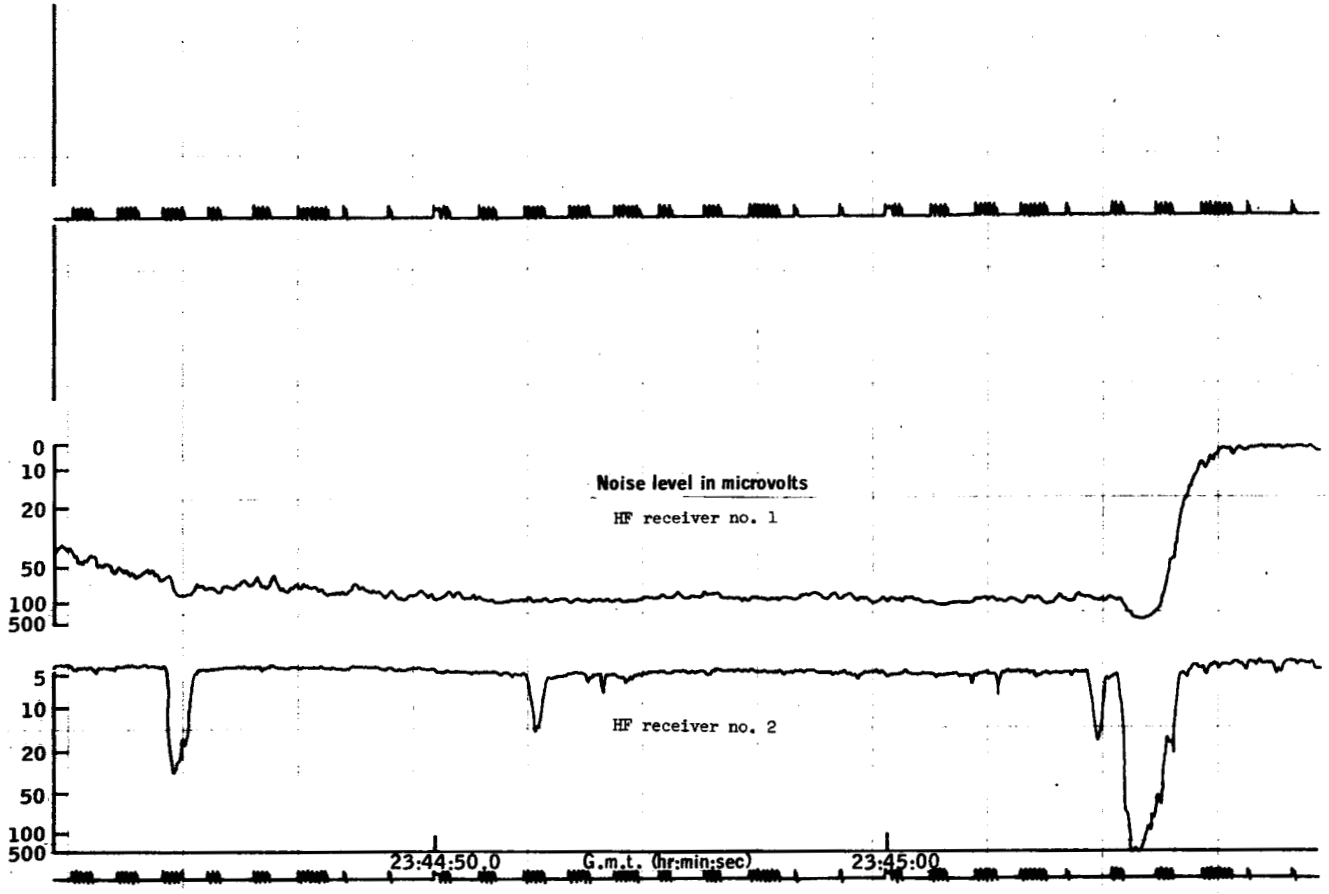

Figure 4-1.- Tracking Station KNO, signal strength chart.

5.0 CONCLUSIONS

The most significant results of the tests indicate that:

(1) Tone was received intermittently by seven of the network stations providing coverage approximately 75 percent of the time.

(2) Good voice quality can be assured with weak signals of 2 to 4 μV provided the signal plus noise-to-noise ratio is 10 or more decibels, and under conditions of no multipath propagation.

(3) Tone reception was received by the Coastal Sentry ship stationed at 21° N latitude and 125° E longitude (an area of low noise) at a maximum great circle distance of 8000 statute miles.

(4) The high noise and RF interference levels in the Caribbean and in southern Africa were mostly responsible for the lack of either tone or voice reception by stations located in those areas.

(5) On three occasions the voice recorded on the magnetic tapes was loud but garbled and unreadable. This suggests that the signals were being received over more than one path (i.e., being affected by multipathing). Multipathing effects are characteristics very common to communications at high frequencies using amplitude modulation of the carrier. As a means of minimizing the effects of this problem in future spacecraft high frequency communication systems, the use of single side, band techniques should be investigated thoroughly.

(6) The limited data obtained during the Gemini V mission indicate that: (a) the spacecraft propagation path is not along the great circle path between the transmitting and receiving antennas as in point-to-point ground communications, but rather by a combination of ducting and reflection off the ionosphere, and (b) the ground HF stations should be located in areas of low atmospheric noise rather than along the Gemini ground track. However, data in addition to signal level received together with information regarding the ionosphere structure is necessary to confirm these assumptions.

(7) The 8-channel Sanborn recorders, type 958, used at most network stations to record the incoming signal strength, are calibrated between 0 and 500 μV in steps of 5, 10, 20, 50, 100, 250, and 500 μV. The incoming signal strength is obtained from a measurement of the automatic gain control voltage which is proportional to the signal at the receiver input. Because most ground stations are provided with Collins Radio, type R-390-A/URR, receivers which employ delayed AGC, the delay is incorporated so that the receiver output voltage is not reduced (no AGC

voltage developed) until the output has exceeded a desired level. Consequently, the data thus obtained are not accurate for use in resolving weak signals (5 μV or less). Several of the S/S charts submitted did not indicate deflection for signals between 0 and 5 μV, see figure 4-1. Only one station, see figure 3-2, submitted a S/S chart showing deflection of approximately 1 inch for a signal of 5 μV. At the global distances, the Gemini HF communication link is normally used, and the signal received at the ground station will seldom be more than 2 or 3 μV. Therefore, if the station charts are to be useful in system evaluation, the recorder calibrations must be affected to permit maximum deflection for signals between 0 and 5 μV.

During the test there were occasions when a tone signal was received, but it could not be identified as the Gemini 1000 cps tone or as a signal from some interfering source. The addition of a periodic interruption of the HF carrier would provide a simple identifying code.

6.0 RECOMMENDATIONS

Further tests similar to those made during the Gemini-V mission should be made to provide a greater sampling of the data; these data are necessary to completely evaluate the future possibilities of HF as a reliable means of beyond-the-horizon communications between the earth and the spacecraft orbiting in the ionosphere. Also, the frequency band between 30 and 40 Mc/sec should be evaluated experimentally for possible use in lieu of the present Gemini frequency of 15.016 Mc/sec. This would minimize the noise problem prevalent on the presently used frequency and would take advantage of the skip reception as well as the ducting between the ionosphere layers characteristic of the lower limit of the VHF band.

To permit resolution of the signal strength necessary for a detailed evaluation of system performance, the network stations should sample the signal at the input to the preamplifiers, and the recorder calibrations should be affected so that lower signal levels (0 to 5 μV) will produce maximum pen deflection of the Sanborn recorders. A deflection of 1 inch for a signal of 5 μV would permit a more accurate evaluation of the incoming signal.